

**METHOD FOR FORMING SAC USING A DIELECTRIC AS A BARC
AND FICD ENLARGER**

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METHOD FOR FORMING SAC USING A DIELECTRIC AS A BARC AND FICD ENLARGER

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of U.S. Provisional Patent Application 60/239,395
5 filed on October 10, 2000, which is incorporated herein by reference thereto.

TECHNICAL FIELD

The present invention relates generally to semiconductors and more specifically to an
improved fabrication process for making Self-Aligned Contact (SAC) semiconductor
memory devices using a dielectric material (SiON) for a Bottom Anti-Reflective Coating
10 (BARC) and a Final Inspection Critical Dimension (FICD) enlarger.

BACKGROUND ART

In general, memory devices such as a Flash electrically erasable programmable read
only memory (EEPROM) are known. EEPROMs are a class of nonvolatile memory devices
that are programmed by hot electron injection and erased by Fowler-Nordheim tunneling.

15 Each memory cell is formed on a semiconductor substrate (i.e., a silicon die or chip),
having a heavily doped drain region and a source region embedded therein. The source
region further contains a lightly doped deeply diffused region and a more heavily doped
shallow diffused region embedded into the substrate. A channel region separates the drain
region and the source region. The memory cell further includes a multi-layer structure,
20 commonly referred to as a "stacked gate" structure or word line. The stacked gate structure
typically includes: a thin gate dielectric or tunnel oxide layer formed on the surface of
substrate overlying the channel region; a polysilicon floating gate overlying the tunnel oxide;
an interpoly dielectric overlying the floating gate; and a polysilicon control gate overlying the
interpoly dielectric layer. Additional layers, such as a silicide layer (disposed on the control
25 gate), a poly cap layer (disposed on the silicide layer), and a silicon oxynitride layer
(disposed on the poly cap layer) may be formed over the control gate. A plurality of Flash
EEPROM cells may be formed on a single substrate.

A Flash EEPROM also includes peripheral portions which typically include
input/output circuitry for selectively addressing individual memory cells.

The process of forming Flash EEPROM cells is well-known and widely practiced throughout the semiconductor industry. After the formation of the memory cells, electrical connections, commonly known as "contacts", must be made to connect the stack gated structure, the source region and the drain regions to other part of the chip. The contact process starts with the formation of sidewall spacers around the stacked gate structures of each memory cell. An etch stop or liner layer, typically a nitride material such silicon nitride, is then formed over the entire substrate, including the stacked gate structure, using conventional techniques, such as chemical vapor deposition (CVD). A dielectric layer, generally of oxide such as boro-phospho-tetra-ethyl-ortho silicate (BPTEOS), is then deposited over the etch stop layer. A layer of photoresist is then placed over the dielectric layer and is photolithographically processed to form the pattern of contact openings. An anisotropic etch is then used to etch out portions of the dielectric layer to form source and drain contact openings in the oxide layer. The contact openings stop at the source and drain regions in the substrate. The photoresist is then stripped, and a conductive material, such as tungsten, is deposited over the dielectric layer and fills the source and drain contact openings to form so-called "self-aligned contacts" (conductive contacts). The substrate is then subjected to a chemical-mechanical planarization (CMP) process, which removes the conductive material above the dielectric layer to form the conductive contacts through a contact CMP process.

For miniaturization, it is desirable to form the self-aligned contacts as precisely and as finely as possible. However, the small geometry of the self-aligned contact mask for accomplishing this is a very difficult challenge for conventional lithographic processes.

A solution, which would allow further miniaturization of memory device without adversely affecting device performance or yield by increasing the process margin for the lithographic process has long been sought, but has eluded those skilled in the art. As the demand for higher performance devices and miniaturization continues at a rapid pace in the field of semiconductor, it is becoming more pressing that a solution be found.

DISCLOSURE OF THE INVENTION

The present invention provides a method for manufacturing a semiconductor device on a semiconductor substrate using the combination of a tapered opening in a bottom antireflective coating (BARC) and a tapered contact opening in a dielectric layer to permit a photoresist contact opening to be larger for a given contact opening so both the Develop

Inspection Critical Dimension (DICD) and the Final Inspection Critical Dimension (FICD) are enlarged for a given line geometry. This permits placing the stacked gates closer together to shrink the size of the integrated circuits.

5 The present invention further provides a semiconductor device having a tapered contact, which permits the closer placement of the stacked gates to shrink the size of the integrated circuits.

The above and additional advantages of the present invention will become apparent to those skilled in the art from a reading of the following detailed description when taken in conjunction with the accompanying drawings.

10 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 (PRIOR ART) is a plan view of a conventional memory device;

FIG. 2A (PRIOR ART) is a schematic diagram of a portion of a memory cell array;

FIG. 2B (PRIOR ART) is a plan view of a portion of an intermediate state (partially complete) of a cell array core;

15 FIG. 2C (PRIOR ART) is a simplified cross section of FIG. 2B (PRIOR ART) along line A--A;

FIG. 2D (PRIOR ART) is a simplified cross section of FIG. 2B (PRIOR ART) along line B--B;

FIG. 3A (PRIOR ART) through 3E (PRIOR ART) illustrate the sequence of process steps of a conventional process for forming source/drain (S/D) contacts in a portion of a cell array core; and

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FIG. 4A through 4F illustrate the sequence of process steps of a process in accordance with the present invention for forming source/drain (S/D) contacts in a portion of a cell array core.

25 BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to FIG. 1 (PRIOR ART), therein is shown a plan view of a conventional memory device, a Flash EEPROM 100 which commonly includes a semiconductor substrate 102 in which one or more high-density core regions and one or more low-density peripheral portions are formed. High-density core regions typically include one or more M x N array cores 104 of individually addressable, substantially identical memory

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cells 200. Low-density peripheral portions 106 typically include input/output (I/O) circuitry and circuitry for selectively addressing the individual cells. The selective addressing circuitry typically includes one or more x-decoders and y-decoders, cooperating with the I/O circuitry for connecting the source, gate, and drain of selected addressed cells to
5 predetermined voltages or impedances to effect designated operations on the cell, e.g., programming, reading and erasing, and deriving necessary voltages to effect such operations.

Referring now to FIG. 2A (PRIOR ART), therein is shown a schematic diagram of a portion of a memory cell array in which each cell 200 in array core 104 typically comprises: a source 202, a drain 204 and a channel 206 (shown in FIG. 2C (PRIOR ART)) semiconductor
10 regions.

Referring now to FIG. 2B (PRIOR ART), therein is shown a plan view of a portion of an intermediate state (partially complete) of a cell array core 104.

Referring now to FIG. 2C (PRIOR ART), therein is shown a simplified cross-section of FIG. 2B (PRIOR ART) along line A--A. The source 202, drain 204, and channel 206
15 semiconductor regions are shown formed in semiconductor substrate 102 (or in an isolation well); and a multi-layer structure, commonly referred to as a "stacked gate" (word line) structure 210. Stacked gate structure 210 includes: thin gate dielectric layer 212 (commonly referred to as the "gate oxide") formed on the surface of semiconductor substrate 102 overlying channel 206; a floating gate 214 overlying the gate dielectric layer 212; an
20 interpoly dielectric 216 overlying floating gate 214; and a control gate 218 overlying interpoly dielectric layer 216. Additional layers, such as a silicide layer 224 (disposed on the control gate 218), a poly cap layer 226 (disposed on the silicide layer 224), and a silicon oxynitride layer 228 (disposed on the poly cap layer 226) may be formed over the control gate 218. Cells 200 are arranged in a series of rows and columns.

25 In the completed array, the control gates 218 of the cells 200 in a row are formed integral to a common word line (WL) associated with the row. Columns of cells are arranged such that adjacent cells in a column share a common semiconductor region as a source or drain region. The source 202 of each cell in a column (excepting end cells) is formed in a common region with one of the adjacent cells, e.g., the preceding cell in the column.
30 Likewise, the drain of the cell is formed in a common region with the drain 204 of the other adjacent cell, e.g., the next succeeding cell in the column (except end cells). The drain of each cell in a column of cells is connected by a conductive bit line (BL) (FIG. 2A (PRIOR ART)), including an overlying layer of metal connected to each drain 204 of the cells 200

within the column. Additionally, the sources of each cell 200 in a row (and hence pairs of rows) are interconnected by a common source line CS (FIGS. 2A (PRIOR ART)) formed in the semiconductor substrate 102, as will be described. Any particular cell 200 within the array cores 104 can be individually addressed (programmed and read) by operating upon one word line and one bit line.

Typically, in forming an EEPROM 100, a pattern of field oxide regions 220 (FIG. 2B) is initially formed to provide electrical isolation between the respective devices of EEPROM 100. For example, field oxide regions 220 are used to provide isolation between the array cores 104 and the devices of peripheral portions 106, as well as between the various columns of cells 200 within the array cores 104. Field oxide regions are conventionally formed using a mask and selective growth process: a layer of thermal oxide ("barrier oxide" or "pad oxide") is grown or deposited over the surface of the semiconductor substrate 102; a mask, frequently composed of nitride, is deposited on the barrier oxide, and patterned to cover those regions of the semiconductor substrate 102 in which devices are to be formed (herein referred to as active regions); field oxide is grown in the exposed areas of the barrier oxide, by for example, the local oxidation of silicon (LOCOS); and the masking layer and barrier oxide are stripped to expose the underlying semiconductor substrate 102. In general, referring to FIG. 2B (PRIOR ART), within the array cores 104, the selective growth process results in alternating parallel strips of field oxide regions 220 and exposed regions corresponding to the columns of cells 200 in the array.

Stacked gate word line structures 210 are then typically formed. For example, gate dielectric layer 212, suitably comprising a thin (e.g. approximately 100 angstroms) layer of oxide, is initially formed on the semiconductor substrate 102 by a suitable technique, such as, for example, thermally oxidizing the surface of the semiconductor substrate 102 or by depositing a suitable material on the semiconductor substrate 102. A layer of suitable conductive polysilicon (e.g., polycrystalline silicon), that will ultimately form the floating gates 214, is typically then formed on the gate dielectric layer 212. For example, conductive polysilicon may be deposited by any suitable technique, e.g., conventional chemical vapor deposition (CVD). The polysilicon layer is typically then masked and etched to remove strips overlying the field oxide regions 220, leaving isolated strips of polysilicon on top of the gate dielectric layer 212 overlying the substrate regions corresponding to the columns of cells 200 of the array core 104 (i.e. the regions in which source, channel, and drain regions of cells in the column will be formed). A layer of suitable dielectric material, such as, e.g., an oxide-

nitride-oxide (ONO) layer, that will ultimately form interpoly dielectric 216 is typically then formed by a suitable technique. For example, where interpoly dielectric 216 is ONO, it is suitably formed by growing a layer of oxide, depositing a layer of nitride, followed by growing another layer of oxide. The interpoly dielectric 216 layer, in the completed array, insulates control gates 218 from floating gates 214 in the individual cells and electrically isolates the adjacent columns of the floating gates 214 in the array core 104. Another layer of conductive polysilicon (e.g., polycrystalline silicon), that will ultimately form the control gates 218 (and the word lines WL connecting the control gates of the cells in the respective rows of the array core 104) is typically then deposited on the interpoly dielectric layer, by a suitable technique, such as, for example, by conventional CVD. Portions of the respective polysilicon and interpoly dielectric layers are typically then selectively removed, to define the stacked gate structures 210 on the gate dielectric layer 212, i.e., to form the floating gates 214, the interpoly dielectric layer 216, and control gates 218 of the individual cells, and the word lines WL (portions of the interpoly dielectric 216 and control gate polysilicon layers, bridge field oxide regions 220, to connect the respective cells of the rows of the core array). This is typically effected by suitable masking and etching techniques.

When completed, this etch creates the respective, generally parallel, word line structures 210 separated by a distance D_{WL} , as shown in FIG. 2C (PRIOR ART). A silicide layer 224 is typically provided over the polysilicon layer 218 to reduce resistance. Thereafter, a polysilicon layer (commonly referred to as a "poly cap" layer) 226 is then formed over the silicide layer 224 to serve as a cap layer for the stacked gate structure 210. Next, a silicon oxynitride layer 228 may be formed over the poly cap layer 226. The combination of the poly cap layer 226 and the silicon oxynitride layer 228 are commonly referred to as a "passivation layer". Thereafter, portions of the poly cap layer 226 and the silicon oxynitride layer 228 are selectively removed using conventional masking and etching techniques to define the final stacked gate structure 210.

Conventionally, the portions of the field oxide regions 220 and the gate dielectric layer 212 between every second pair of adjacent word lines 210 in the array core 104 (i.e., the regions, generally indicated as 222, where the sources 202 are to be formed and the portions of the field oxide regions 220 disposed between sources 202 of the corresponding cells of adjacent columns) are then typically removed, in preparation for formation of the common line CS (not shown)) connecting the sources 202. This is typically effected using a conventional Self-Aligned Source (SAS) etch.

Referring now to FIG. 2D (PRIOR ART), therein are shown a simplified cross section of FIG. 2B (PRIOR ART) along line B--B for purposes of clarity.

In a conventional process, the source 202, common line CS, and drain 204 regions are then formed. The source 202 and the common source line CS are typically formed by initially effecting a conventional double diffusion implant (DDI), with the SAS mask still in place. The DDI implants a first dopant (e.g. n-type, such as phosphorous) to form a deeply diffused, but lightly doped, N well 202_L establishing a graded source-channel junction as shown in FIG. 2D (PRIOR ART). The SAS mask is then removed. The DDI implant is typically driven deeper into the substrate 102 by subjecting the substrate 102 to a thermal cycle at high temperature (e.g. 1050 degrees Celsius). A shallow second implant, commonly referred to as a medium diffused drain (MDD) implant, is then performed (e.g., with arsenic) to create a more heavily doped, but shallower, n+ well 202_H embedded within deep N well 202_L. The MDD implant also forms a shallow, abrupt drain 204.

Referring now to FIGs. 3A (PRIOR ART) through 3E (PRIOR ART), therein is shown the sequence of process steps of a conventional process for forming source/drain (S/D) contacts in a portion of cell array core 104. FIG. 3A (PRIOR ART) shows the formation of sidewall spacers 230 around the stacked gate structures 210a and 210b formed on semiconductor substrate 102. At this stage are shown a channel region 206a separated by a drain 204a and a common source 202ab, and a channel region 206b separated by the common source 202ab and a common drain 202bc. The sidewall spacers 230 are typically formed of a nitride material using conventional deposition and etching techniques. Alternatively, the sidewall spacers 230 may be formed of an oxide material using chemical vapor deposition (CVD) followed by etching.

FIG. 3B (PRIOR ART) shows the deposition of an etch stop layer 231 over the entire substrate 102, including over the stacked gate structures 210a and 210b using conventional techniques, such as CVD. The etch stop layer 231 is typically formed of a nitride material such silicon nitride and is formed to a thickness typically in the range of approximately 30 to 120 nm. The etch stop layer 231 reduces the effective spacing between the stacked gate structures 210a and 210b. A dielectric layer 232 is then deposited over the etch stop layer 231. The dielectric layer 232 may include various oxides, such as boro-phospho-tetra-ethyl-ortho silicate (BPTEOS) or borophosphosilicate glass (BPSG), formed using plasma enhanced chemical vapor deposition (PECVD).

FIG. 3C (PRIOR ART) shows the formation of source/drain (S/D) contact opening 234 in the dielectric layer 232, through etch stop layer 231, using a contact mask 238, to expose portions of the common source 202ab. For simplicity of illustration, only one contact opening 234 is shown. The contact opening 234 is formed conventionally using a two-step etch process. The first etch process is a conventional etch process, such as an oxide etch process, which stops at the etch stop layer 231. The second etch process is a conventional etch process, such as a nitride etch process, which removes portions of the etch stop layer 231 to expose portions of the common source 202ab.

An oversize contact opening 235 shows both the possibility of the contact opening 234 being oversize due to poor lithography at small critical dimensions and being misaligned so that the opening 234 does not fall properly on the common source 202ab. This may result in high contact resistance and poor reliability of the integrated circuit.

FIG. 3D (PRIOR ART) shows the removal of the contact mask 238 and the deposition of a conductive material to form a conductive layer 239 over the dielectric layer 232. The conductive material fills the contact opening 234 which will form a contact 240. The conductive material typically includes tungsten, aluminum, copper, gold, silver, etc., and may be formed using conventional metal deposition techniques, such as CVD and/or physical vapor deposition (PVD). A barrier material (not shown), such as titanium (Ti)/titanium nitride (TiN), is typically deposited to coat the walls of the contact opening 234 prior to the deposition of the conductive material to ensure good adhesion and electrical contact to the walls of the contact opening 234 and the underlying common source 202ab.

Referring now to FIG. 3E (PRIOR ART), therein is shown the removal of conductive material above the dielectric layer 232 using for example, chemical-mechanical polishing techniques. As shown, the contact 240 will have detrimentally high resistance since its entire cross section will not fall directly on the common source 202ab.

As explained in the BACKGROUND ART, one of the problems associated with the small geometry of the contact is that it is both difficult to form and to locate obtain the self-aligning contact. This is becoming critical as separation between adjacent stacked gate structures reduces and the line geometries shrink.

Referring now to FIGs. 4A through 4E, therein is shown the sequence of process steps for forming self-aligning contacts in accordance with the present invention for fabricating EEPROM device on a semiconductor substrate. For convenience of illustration, like reference numerals are used in FIG.4A through 4G to denote like elements already described

in FIGS. 1 (PRIOR ART), 2A (PRIOR ART) through 2D (PRIOR ART), and 3A (PRIOR ART) through 3E (PRIOR ART).

FIG. 4A shows a partial, sectional view of an intermediate state (partially complete) of a portion of a cell array core 104, similar to what was shown in FIG. 3B. At this stage is shown a pair of stacked gate structures 210a and 210b formed on a semiconductor substrate 102. A common source 202ab is formed between the two stacked gate structures 210a and 210b. Drains 204a and 204bc are formed on the semiconductor substrate 102 and are spaced apart from the common source 202ab by channel regions 206a and 206b, respectively. Sidewall spacers 230 are formed around the stacked gate structures 210a and 210b. The sidewall spacers 230 may be formed of an oxide or nitride material using deposition and etching techniques. In this embodiment, sidewall spacers 230 are formed of a nitride material such as silicon nitride. After the sidewall spacers 230 are formed, a dielectric liner layer 231 of a material such as silicon nitride is formed over the entire semiconductor substrate 102, including the stacked gate structures 210a and 210b, sidewall spacers 230, common source 202ab, and drains 204a and 204bc. The dielectric liner layer 231 is in contact with the stacked gate structures 210a and 210b, sidewall spacers 230, common source 202ab, and drains 204a and 204bc. The deposition of the dielectric liner layer 231 is followed by the deposition of a dielectric layer 232 over and in contact with the dielectric liner layer 231.

In this embodiment, each of the stacked gate structures 210a (or 210b) includes a gate dielectric layer 212, such as an oxide layer, a floating gate 214 disposed on the gate dielectric layer 212, an interpoly (inter-gate) dielectric layer 216 disposed on the floating gate 214, a control gate 218 overlying the interpoly dielectric 216, a silicide layer 224 disposed on the control gate 218, a polysilicon (poly cap) layer 226 disposed on the silicide layer 224, and a silicon oxynitride layer 228 disposed on the poly cap layer 226.

FIG. 4B shows the deposition of a Bottom Anti-Reflective Coating (BARC) 233, which in the Best Mode is silicon oxynitride (SiON), over the dielectric layer 232. A photoresist 235 is disposed over the BARC 233 and has been photolithographically patterned, exposed, and developed to form an oversize photoresist contact opening 237. The BARC 233 minimizes reflections from the dielectric layer 232 which could interfere with precise patterning and positioning of the photoresist contact opening 237.

FIG. 4C shows the formation of source/drain (S/D) contact opening 262 in the dielectric layer 232 using the photoresist contact opening 237. A semi-isotropic etch is used which provides a tapered opening 261 through the BARC 233 which has a smaller diameter

proximate the dielectric layer 232. The BARC 233 with the smaller diameter is used as a hard mask for the etching of the dielectric layer 232.

For simplicity of illustration, only one contact opening 262 is shown. To minimize etching of the sidewall spacers 230 and the underlying substrate 102, the contact opening 262 is formed using an oxide etch process with a sufficiently high selectivity, i.e., etching of the dielectric layer 232 is performed with reactive ions at a rate faster than the etch rate of the sidewall spacers and the underlying substrate 102. During the oxide etch process, the silicon oxynitride layers 228 act as protective layers for the stack gate structures 210a and 210b to avoid them from being etched.

In the present invention, the oxide etch is a semi-isotropic etch which provides a tapered S/D contact opening 262. The combination of the tapered opening 261 in the BARC 233 and the tapered S/D contact opening 263 in the dielectric layer 232 permits the photoresist contact opening 237 to be larger for a given contact opening 262 so both the Develop Inspection Critical Dimension (DICD) and the Final Inspection Critical Dimension (FICD) are enlarged for a given line geometry.

FIG. 4D shows the removal of the photoresist 235, the BARC 233, and the dielectric liner layer 231 over the S/D contact 202ab. This removal step allows the photoresist contact opening 237 to be closer to other similar openings without causing contacts which are so close together that they short together.

FIG. 4E shows the deposition of a conductive material to form a conductive layer 269 over the dielectric layer 232. The conductive material fills the contact opening 262. In this embodiment, the conductive material is tungsten and may be formed using conventional metal deposition techniques, such as CVD and/or physical vapor deposition (PVD). Other conductive materials can be used. Thin barrier materials (not shown), such as titanium (Ti)/titanium nitride (TiN) or tantalum (Ta)/tantalum nitride (TaN), may be deposited to coat the walls of the contact opening 262 prior to the deposition of the conductive material to ensure good adhesion and minimize diffusion of the conductive material through the walls of the contact opening 262 or into the underlying common source 202ab.

FIG. 4F shows the removal and planarization of the tungsten material above the oxide layer 232 using for example, tungsten chemical-mechanical planarization technique. The tungsten material is planarized until it is flush with the top surface of the dielectric layer 232.

In production, a plurality of stacked gate structures is formed on a semiconductor substrate 102 using conventional techniques as shown in FIG. 4A. For simplicity of

illustration, only two stacked gate structures, 210a and 210b, are shown. The common source 202ab is formed between the two stacked gate structures 210a and 210b. Drains 204a and 204bc are formed on the semiconductor substrate 102 and are spaced apart from the common source 202ab by channel regions 206a and 206b, respectively. The sidewall spacers 230 are formed around the stacked gate structures 210a and 210b. The sidewall spacers 230 are formed using conventional deposition and etching techniques.

In this embodiment, each of the stacked gate structures (210a or 210b) includes the gate dielectric layer 212, the floating gate 214 disposed on the gate dielectric layer 212, the interpoly (inter-gate) dielectric layer 216 disposed on the floating gate 214, the control gate 218 overlying the interpoly dielectric 216, the silicide layer 224 disposed on the control gate 218, the polysilicon (poly cap) layer 226 disposed on the silicide layer 224, and the silicon oxynitride layer 228 disposed on the poly cap layer 226.

Next, the dielectric liner layer 231 is formed over the entire semiconductor substrate 102, including the stacked gate structures 210a and 210b, sidewall spacers 230, common source 202ab, and drains 204a and 204bc, using high temperature oxidation or plasma enhanced chemical vapor deposition (PECVD) (FIG. 4A).

This is followed by the deposition of the BARC 233 and the photoresist 235. The photoresist 235 is subjected to a photolithographic patterning and developing process to form the photoresist contact opening 237 (FIG. 4B).

Next, the source/drain (S/D) contact opening 262 is formed in the dielectric layer 232 using the photoresist 235 and the BARC 233 as a mask to expose portions of the common source 202ab (FIG. 4C). As explained above, the etch process with high selectivity is used to form the contact opening 262 to minimize etching of the sidewall spacers 230 and the underlying substrate 102. It should be noted that the dielectric liner layer 231 located above the common source 202ab and portions of the dielectric liner layer 231 on the sidewall spacers 230 are removed during this etch process.

Thereafter the photoresist 235 and the BARC 233 are removed using conventional stripping techniques (FIG. 4D).

After the removal of the photoresist 235 and the BARC 233, the conductive material is deposited over the dielectric layer 232 to form the conductive layer 269. The conductive material fills the contact opening 262 (FIG. 4E). In one embodiment, the conductive material is tungsten and is formed using conventional metal deposition techniques.

After the formation of the contact 270, conductive material above the dielectric layer 232 is removed using a planarization technique, such as chemical-mechanical polishing (FIG. 4F).

Therefore, the present invention provides a method for shrinking a semiconductor device and enlarging the FICD.

While the best mode utilizes tungsten as the conductive material for filling contact openings, it should be understood that the present invention is applicable to other materials selected from a group consisting of tantalum, titanium, copper, aluminum, gold, silver, alloys thereof, and compounds thereof.

While the invention has been described in conjunction with a specific best mode, it is to be understood that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations which fall within the spirit and scope of the included claims. All matters hither-to-fore set forth herein or shown in the accompanying drawings are to be interpreted in an illustrative and non-limiting sense.